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Effect of Annealing on the Structure and Optical properties of InGaAs/GaAs Quantum Dots

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In this paper, we report the effect of annealing on self-assembled InGaAs/GaAs quantum dots, as investigated by means of resonant photoluminescence (PL), resonant Raman scattering, polarization dependent PL, and high resolution X-ray diffraction.

Two InGaAs/GaAs quantum dot samples are grown in Stranski-Kranstnov (SK) mode by solid source MBE, on (001) oriented undoped GaAs substrates. A 5-monolayer-$In_{0.5}Ga_{0.5}As$ QD layer was embedded in the GaAs matrix. One sample was in-situ annealed at $660^0 C$ for 11 minutes under As overpressure.

Figure 1 shows the PL spectra excited at different energies (E_{ex}) at 10 K. At $E_{ex} = 1.3883eV$ close to the edge of the density of states in the wetting layer, a resonant PL peak appears on the high-energy shoulder of the broad PL band excited non-resonantly ($E_{ex} = 1.9592eV$), for both the as-grown and annealed samples. Resonant Raman scattering peaks are also observed in Fig. 1, the LO phonon energy of InGaAs in the annealed sample (34.2 meV) is higher than in the as-grown sample (33.9 meV), which means the Indium composition in the QDs of annealed sample is lower than that of as-grown sample.

Figure 2 shows the polarization of surface-emitted PL from the as-grown and annealed samples. The PL polarization anisotropy P is defined as $(I_{[1\bar{1}0]} - I_{[110]})/(I_{[110]} + I_{[1\bar{1}0]})$, where $I_{[110]}$ and $I_{[1\bar{1}0]}$ are intensities polarized along the $[110]$ and $[1\bar{1}0]$ directions, respectively. The value of P is indication of the elongation of QDs along $[1\bar{1}0]$ with respect to $[110]$ due to anisotropic surface diffusion of indium. As shown in Fig.2, little change in the anisotropy P can be seen for the as-grown and annealed samples.

Figure 3 shows the high-resolution X-ray diffraction (XRD) rocking curves around the GaAs (004) peak. It can be seen that the fringes in the range of –1000 to –1500 arcsecs evolve into a broad tail for the annealed sample, which means the strain relief occurs in the growth direction during annealing the QDs' sample.

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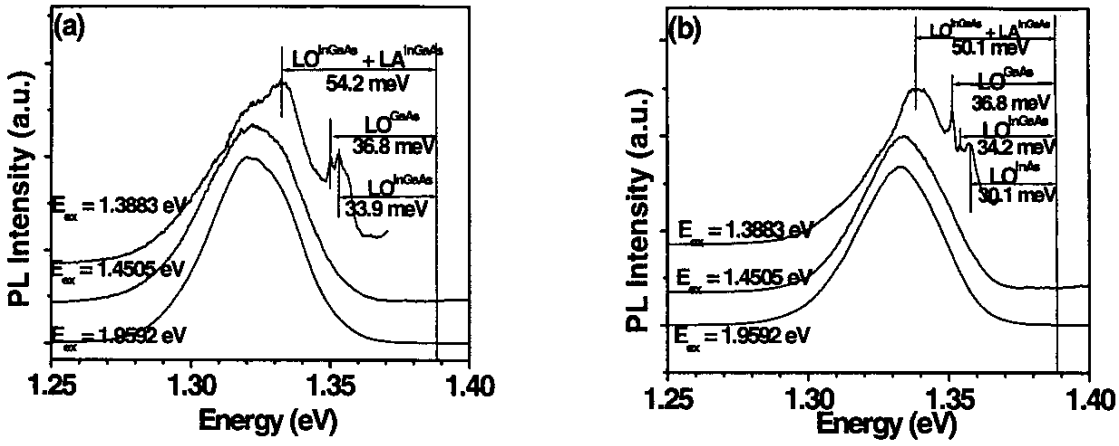

Fig. 1 PL spectra at different excitation energies at 10 K, for (a) the as-grown sample, and (b) the annealed one

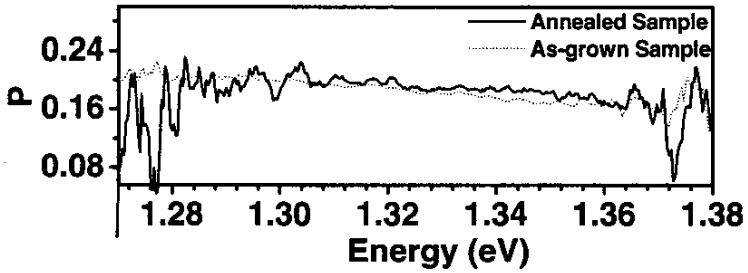

Fig. 2 PL polarization anisotropy measured at 10 K

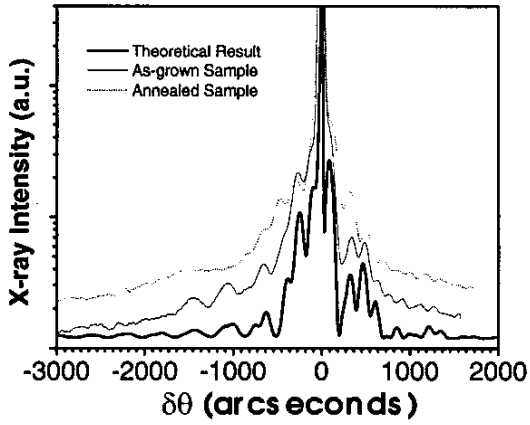

Fig. 3 High resolution XRD rocking curves around GaAs (004) peak